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Sustainable agriculture development on tropical peatland

MELLING Lulie (1), **RYUSUKE Hatano** (2) **and MITSURU Osaki** (2)

(1) Department of Agriculture Sarawak, Malaysia
(2) Faculty of Agriculture, University of Hokkaido, Japan

Abstract

Sarawak is a state in Malaysia that has a land area of 12.4 million hectares. It has approximately 1.7 million ha of peat swamp covering almost 13% of the total land area of the state. In pursuit of the government policy of placing the plantation sector as one of the important export-oriented industries, millions of ringgit has been spent both by the government and private sectors to tap the economic potential of these lands. More than 400,000 ha of these lands have been alienated for agriculture plantation and reforestation.

As suggested by Melling (1999b), peat resource is a goldmine for the state. It has great potential to be developed into agriculture plantation. A proper and efficient utilization of these lands for agriculture would contribute significantly towards a long-term economic growth of the state. However, its economic usefulness would be short lived and the state may loose one of its most valuable resources if its utilization is not well managed.

The tropical peat of Sarawak, is one of the most fragile wetland system in the world. It is a non-renewable resource because once it is destroyed, it will be gone forever. Peat development is like a time bomb (Melling, 1999b) that must be handled in utmost care. Therefore it is very important that potential risk that comes together with any peat development must be well understood and anticipated by everyone involved. If it is not well managed, it may cost an ecological degradation. Thus it is very important to ensure that any agriculture development on the peat is equitable and ecological sustainable.

Keywords: water management, tropical peat, sustainable drainability, sustainable agriculture

Introduction

Tropical peatland is a very valuable non-renewable natural resource that can be developed into agriculture plantations and thus contributing towards a long-term economic growth (Melling, 1999b). It is a very fragile and eco-sensitive wetland that must be treated with utmost understanding and care. Any improper human intervention may shorten its economics usefulness. It may also lead to its degradation and eventual destruction. More seriously, it can cause an irreversible ecological catastrophe.

Today, more and more tropical peat land is being cleared and converted into agriculture plantations in search for economic return. Some have proved to be a an economic success while others have ended with an ecological disaster. This was the case in Indonesia. In 1997, one million hectare of pristine tropical peat in Central

Kalimantan was cleared for a Mega Rice Project (Limin and Jamal, 2000) to meet Indonesia's self-sufficiency in rice. However, it has ended with an ecological disaster as no serious consideration was given to the danger and risk associated with peat development. This case serves as a warning to everyone concerned with peat land development. Unless the whole process is properly planned, managed, monitored and controlled, we will not only loose our source of income but more seriously we may also loose our invaluable heritage and thus causing ecological imbalance.

This paper discusses the tropical peat land of Sarawak and the issues associated with its development for agriculture. It focuses on the properties of Sarawak peat land, the problems associated with its development and the importance of water management for sustainable agriculture.

Tropical peatland of Sarawak

Sarawak is the largest state in Malaysia. It has a land area of approximately 12.4 million hectares, of which 1.7 million hectares is covered with tropical peat land. It is the largest tropical peat swamp in the country covering almost 13% of the land area of the state. It constitutes almost 63 percent of the total peat land of the country. The Sarawak peat swamp can be found as a continuous strip along its coast, usually situated 2 to 4 km inward. They are formed on the inward edge of the mangroves. It covers a large proportion of the drought-prone coastal plain of Sarawak See Figure 1

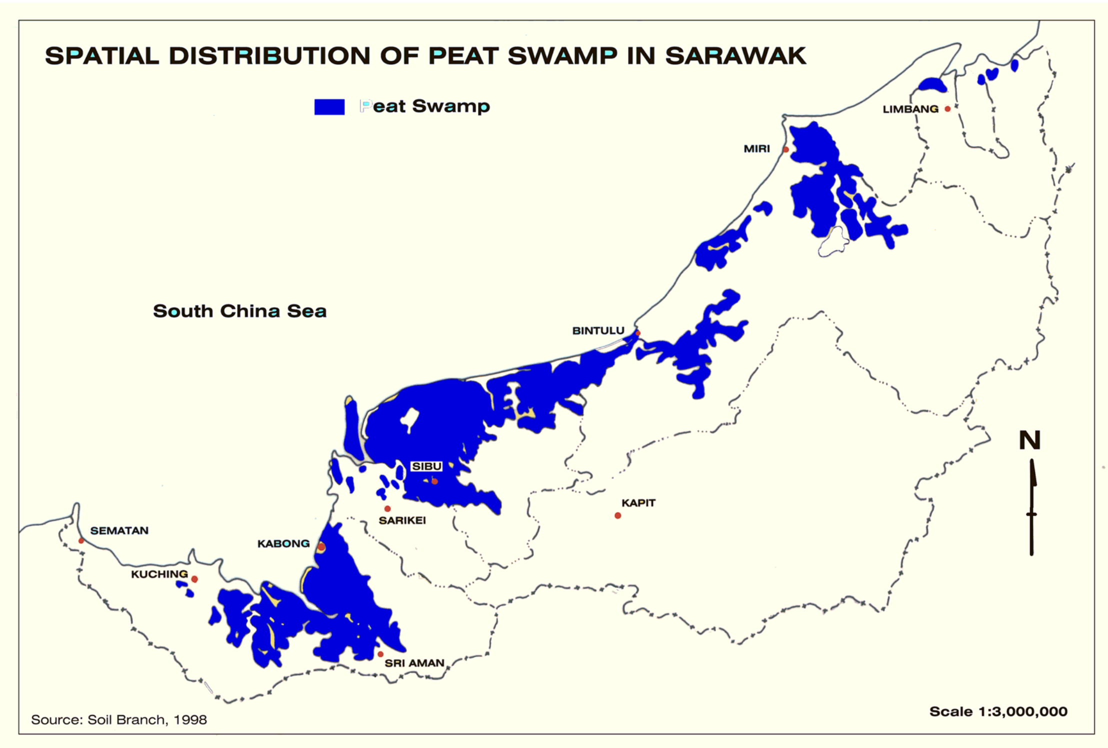

Figure 1 Spatial distribution of peat swamp in sarawak.

Peatland is considered as a goldmine for Sarawak because it has great potential to be developed into agriculture plantation that would contribute towards the state's long-term economic growth (Melling, 1999b). The government policy of placing the plantation sector as one of the state's core export-oriented industries, an increasing shortage of good agricultural land, the flat topography and the close proximity of these lands to the existing crop areas and population centres, have all led to a marked intensification of agriculture development on peatland for the last seven years. Since then, more than 400,000 hectares have been alienated both for agriculture development and reforestation (Melling, 1999b).

The tropical peat land of Sarawak is one of the most fragile wetland systems in the world. Therefore, it is very critical for Sarawak to properly and smartly managed the development of its peatland for agriculture. It is to ensure that the bio-diversity and economic usefulness of these lands are maintained. It has been said that "the management of human use of the biosphere so that it may yield the greatest sustainable benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations". It advocates sustainability and maintenance. In this paper, the focus is on the sustainable agriculture development on peatland, the emphasis of which is not on the maximisation of production but sustaining productivity over a long period of time for long-term economic benefits.

The suggestion by the Technical Advisory Committee (TAC) of the Consultative group on International Agricultural Research (CGIAR) defined that "sustainable agriculture should involve the successful management of resources to satisfy the changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources" is very apt (TAC, 1989). However, in this case the emphasis is more on prolonging the economic usefulness of the peat land and maintaining its bio-diversity through successful water management. But before going into detail the aspects of water management, it is very appropriate to discuss the properties of the peat land and the problem associated with its development for agriculture.

The characteristics and properties of Sarawak peat land

It is estimated that about 90% of the total peat land in Sarawak is classified as deep peat (depth of >1.5 m). The individual peat bodies range from a few to 100,000 hectares and they generally have a dome-shaped surface. The peat are generally classified as the ombrogenous peat (rainfed) and therefore poor in nutrients (oligotrophic). Due to coastal and alluvial geomorphology they are often elongated and irregular, rather than having the ideal round bog shape. Most of the coastal peat swamps are elevated well above adjacent river courses, varying from about 4 metres near the coast to more than 9 metres inland. Surface slopes vary between 1 and 2 m km^{-1} at the sides of the domes near the adjacent channel sides, but in the central parts of the peat-domes the slope is often below 0.5 m km^{-1}. The depth of the peat is shallower near the coast and increases land inwards; locally exceeding more than 10 m although up to 20 m has been recorded (Anderson, 1961).

These properties makes water table control very complex especially when the alienation of these lands for agriculture is made in small individual pockets of about 5,000 hectares each within a peat basin.

Peat hydrology

Hydrology is a vital key to the peat land ecosystem functioning. Even though the hydrological behaviour of the tropical peatland is not clearly understood, rainfall and surface topography is believed to regulate the overall hydrological characteristics of the natural peat swamp. The drainage are mostly radial due to its convex surface and diffuse i.e. near surface-flow occurs rather than channel-flow. Surface runoff concentrates in shallow depressions, from where small rivulets are formed that turn into larger streams and finally into navigable streams. Water levels in the centre of peat-swamps are reported to be lower than at the periphery, under natural conditions (Tie and Kueh, 1979), as levels at the periphery are maintained by lowering of the water table in the centre (Anderson, 1964). The ground water flow of the peat is influenced by the recharge to the water table (rainfall minus crop evapotranspiration) and the soil hydraulic parameters (drainable pore space, hydraulic conductivity, and the thickness of the peat layer). The high infiltration, water holding and transmitting capacity of the peat (Ong and Yogeswaran, 1994) influences the relatively small fluctuations in the water table, even during periods of high rainfall. The flow velocity within the peat basin can exceed more than 30 m d^{-1}.

However, the topo-hydrological characteristic of the peat swamp makes water table control in peat development more complex. The prerequisite for any agriculture development on peat is proper drainage. Without drainage, crop establishment is difficult, as crops cannot breathe through their root system.

Physical properties

The peat materials are raw and very woody with preserve tree trunks, branches and large roots present in abundance. It has a high moisture content and water holding capacity of 15-30 times of their dry weight (Tay, 1969). The high water content results in high buoyancy and high pore volume leading to low bulk density and low bearing capacity. The ash content can be less than 10% (Wong, 1994; Melling, 1997) showing a very high content of organic matter. This is indicated by a loss of ignition value exceeding 90% (Melling, op cit).

The common soil profile morphology of Sarawak peat consists of three distinct layers differentiated by its level of humification. They are the sapric, hemic and fibric as it goes down the soil profile. In the virgin peat dome, sapric materials may be absent, and the hemic layer can be less than 20 cm. For any agriculture development, it is necessary to increase the thickness of the sapric/hemic layer. This is done by increasing the aerobic layer by drainage. The prerequisite to successful agriculture development on the peat land is proper water table control through drainage. Drainage is also necessary to lower the water table of the peat land so as to increase its bearing capacity to support mechanisation.

However, it has led to over-drainage that causes a chain of problems (Melling, *et al.,* 1999; Melling, 1999). It increases the rate of subsidence, occurrence of flooding, reduction in the water holding capacity, increase in the occurrence of acid-sulphate soils, forest fire, pest infestation and termite attack, and nutrient imbalance (Aminuddin, 1994; Andriesse, 1994). It also shows a decrease in the crop yield. Excessive drainage of the peat will cause a transformation of its colloids resulting in it having the properties of irreversible drying.

The peat soils are very dynamic. This is because the peat will undergo subsidence and oxidation upon drainage. Initially, it involves principally the loss of buoyancy and compaction of the organic column under its own weight. These results in the changes in the hydropedological parameters like the hydraulic conductivity, bulk density, pore volume and moisture content. The subsequent dominant process that may last for decades is the oxidation and shrinkage. The rate of subsidence varies strongly depending on the peat profile morphology, peat composition, peat depth, depth of drainage and land use. Due to the differential rate of subsidence upon drainage, the micro relief of the peat surfaces becomes hummocky. The differential height of the micro relief can be as much as 50 cm (Melling, 2000). A subsidence of 100-150 cm can be expected within the first 3 years of large-scale development especially in the former Alan Forest (*Shorea albida*) areas. This is because of the rampant existence of a vacant layer (Yonebayashi, 1995; Melling, 2000) and the high porosity of the peat.

Peat subsidence has several serious consequences. Drainage needs to be regularly adapted to new levels and conditions, otherwise inundation and flooding will recur. The rooting systems, particularly of perennial species become exposed, and top-heavy crops such as oil palms start to lean over and are partly up rooted. Roads and other structures become unstable. Designing an efficient water management system in Sarawak peat land is also made more complex by the following factors:

(1) The rainfall is not well distributed throughout the year
(2) The spatial variation of the rainfall along the coast of Sarawak
(3) High variation in the hydraulic conductivity or permeability
(4) High fluctuation of the water table

Chemical properties

The chemical properties of the peat depends on the thickness of the organic horizon, the nature of the subsoil, the botanical composition and the degree of decomposition. The peat soils are very acidic in nature with a pH of 3.7. They have a high CEC of 150 me 100 g^{-1}. Thus these soils are strongly buffered. But the high CEC is not due to the presence of Na, K, Mg or Ca but because of the presence of exchangeable H^+. The peat has very low amounts of exchangeable bases causing them to have low percentage base saturation. The N content of peat is rather high but its availability for plant uptake is rather low. The high C: N ratio (40: 1) coupled with the low pH results in low mineralisation in peat. The peat is highly deficient in micronutrients such as Cu and B (Ambak *et al.*, 1991; Ambak and Tadano, 1991).

Water management for sustainable agriculture

As mentioned, millions of ringgit had been spend both by the government and private sector to tap the economic potential of the vast peat land of Sarawak. Many hectares of the land have been developed into agriculture plantation. However the results are not encouraging. The alienation and eventual development of these lands for agriculture has brought to light many unanticipated problems and complexities. These problems and complexities can be traced to one common element i.e. water control. It has been suggested that controlling and maintaining the water table is the pre-requisite to the sustainable peat land agriculture development. The Food and Agriculture Organisation has stated that “not withstanding the fact that land is indispensable for agricultural production, it is water rather than land, which is the binding constraint. It is only when this water constraints is released that other technical constraints such as nutrients and pests become important” (Ridzuan and Abdullah, 1992). It gives utmost importance to the proper and efficient water management to control and maintain the required water table while not forgetting other constraining elements.

Water management refers to the sets of managerial decisions and actions to balance the drainage requirements and at the same time maintaining the water level within the optimum range for crop production. It emphasise on the application of an appropriate water table control to match crop requirement, control of over drainage and conservation of water resources.

Since agriculture development on peat is the long-term commitment of the state and that it involve very large land area, it is most appropriate to consider water management from the perspective of strategic management. From strategic management viewpoint, a proper water management involves process of collecting and analysing data and information about peat and its environment, the formulation of strategy and policy, strategy implementation, co-ordination, evaluation and control.

Scanning the peat properties and its environment

One of the major concerns in connection with peat development is that the plantation activities were carried out on an unknown terrain. The peat type in the development areas have not been properly characterized and mapped out. Proper analysis and evaluation cannot be carried out when data or information on the peat characteristics, peat hydrology and its agriculture potential are lacking or insufficient. It has also make the planning and management of the peat development lack of direction and disorganized. There is a fundamental lack of knowledge about the ecology of peat swamp amongst the planners and policy makers. Many of those involve in the development do not have the knowledge or do not realize the complexity and risk of developing the tropical peat for agriculture. The main aim of this process is to collect crucial data and information about peat and its environment and to establish the water drainage requirements of the various types of crop, the impact of drainage on the hydrology, bio-diversity and sustainability of the peat and to evaluate the various drainage systems.

This process involves site survey, field experiments and observation to study the peat land itself in term of its properties, characteristics and bio-diversity and studying the various crops in term of their properties, behaviour, suitability and their water requirements. It also involves synthesising, analysing and evaluating the various water drainage options and identifying the complexity and risks that may be encountered.

Strategy and policy formulation

Strategy[1] formulation is the process of developing a long-term plans for a sustainable agriculture development on peat land. It includes specifying a clear aim and objective, developing plans and setting policy guidelines of water management. For example, in order to ensure a well co-ordinated peat land agriculture development programme, it is appropriate to establish a Peat Development Co-ordinating Unit. One of the functions of this unit is to co-ordinate the implementation of water management programmes. Another strategy that can be drawn up to improve the water management is to establish a Peat Research and Management Institute that will be responsible for collecting, collating, keeping and disseminating peat data and information (including information on water drainage requirements of various plantations and the standards, guidelines and procedures on proper water control).

[1] A **strategy** is a comprehensive master plan stating how the objectives of water management for peat land agriculture development can be achieved.

Once the strategy is formulated, it is necessary to set policy[2] guidelines that form a broad guidance for all parties to follow when making decisions and taking actions in connection with water control and maintenance. It is a controlling mechanism to ensure that all activities in connection with agriculture development and its water control and maintenance, are properly carried to achieve the objective.

As an example, there should be a policy on how peat land should be alienated and which crop should be planted as not to have a conflict of water table requirement. Another policy that may be introduced is that land alienation can only be made after an environmental impact assessment report and a water drainage design proposal have been approved.

Strategy implementation

Once the strategy and policy have been formulated, it must be put into action through the development of programs, budgets, standards and procedures. In implementing the strategy, it is necessary to address these questions – "Who are the people who will carry out the plan?", "What must be done?" and "How are they going to do what is needed?". In the context of water management, these questions must be asked each time the pro and cons of the various drainage systems are evaluated in search for the most viable solution.

Who are the people who will carry out what is needed?

The question of "who will carry out the plan" is concerned with identifying the department or agency responsible for the overall implementation of the strategy and policy. As in the case of Sarawak, the responsibility for the overall implementation of the peat land development strategy and policy contained in the state agriculture policy lies with the Ministry of Land Development. It is now drawing up a strategy and policy for the development of peat land for agriculture based on the state agriculture policy. Now, it is also embarking on a study to formulate its water management strategy and policy.

Once such strategy and policy have been formulated, it is imperative for the ministry to identify or more drastically, set up an agency to put the strategy and policy into action. This is in line with the concept of strategic management where the group that implements the strategy should be different from that formulating the strategy and policy. The failure identifying the agency that is actually responsible for peat development management may result in confusion as to who is doing what, especially among various other related agencies.

What must be done?

Once identified or established, it is very crucial for this agency to draw up a comprehensive programme[3], standard and procedure[4] and budget as part of its activities in the implementation of the water management strategy and policy. Programme, standard and procedure and budget are simply more greatly detailed plans for the eventual implementation of the ministry's strategy and policy. It is a plan of work for achieving the desired objectives. In some cases water management activities has been

[2] A **policy** is a broad guidelines for decision making throughout an organisation.

[3] A **programme** is a statement of the activities or steps needed to accomplish a single purpose plan, in this water management programme.

[4] A **standard** and **procedure** are systems of sequential steps or techniques that described in detail how a particular task or job is to be done.

carried out in *ad hoc* manner without any proper schedule, guidelines, procedure or standard and thus giving rise to chains of problem.

How are they going to do what is needed?

The implementation of the water management strategy and policy involve several other action-oriented activities namely – organising, staffing, directing, co-ordinating, monitoring and controlling. Therefore, before the strategy and programme can lead into actual performance, the top management of the responsible agency must ensure that there is a proper organisation and that all programme or activities are adequately staffed with qualified and experience personnel. As defined, structure of an organisation (in this case the responsible agency) is its formal arrangement of people's roles, responsibilities and inter-relationship between them. Sometimes it is also called chain of command.

In the case of Sarawak, the ministry are now in the process of rationalising the organisational structure for the implementation of peat development and water management programme. The organisation will include people from the various related agencies. However, in rationalising the organisation, it is important for the ministry and the agency concerned to give due attention not only to the Sarawak vast peat land area but also the amount, complexity of the tasks to be accomplished and the risks involved.

At the same time, the agency has to design an effective monitoring, reporting, evaluation and control system to ensure that all activities are carried out according to the standard and procedures and directed towards achieving the desired objectives of its water management. In this case, it is appropriate for the agency to exploit the current state of information technology by establishing a digital database for peat land of Sarawak, particularly for area already with agriculture plantation and to develop a system to analyse peat behaviour, its changes and impact on sustainability of the peat land and its resources.

Conclusions

It should be borne in mind that drainage bleeds the peat swamp the very medium that is its basis of existence. Over drainage will accelerate the rate of subsidence, which will trigger all the problems related to it. Thus it is very important that the drainage system for peat are based on the concept of controlled drainage in order to minimise the inevitable process of irreversible subsidence, and at the same time still able to sustained its economic and ecological usefulness for a long time.

Since the peatland of Sarawak is invaluable heritage and its area is almost 1.7 million ha, it is most appropriate that the water management associated with agriculture development be considered from the prospective of strategic management. As mentioned, strategic management is concerned with long-term performance of business organisation, so is the objectives of sustainable agriculture.

It should be well understood, however that, even with the best water management, subsidence cannot be arrested. It is the price one has to pay for the use of tropical peatlands. The irreversible process of subsidence can only be arrested only through complete re-saturation of the peat (Schothorst, 1982; Salmah *et. al.,* 1994; Stewart, 1994). There should be a continued collaboration between drainage engineers and agricultural scientists to look for optimum ways of controlling the subsidence of peat especially by appropriate water management. Therefore, the sustainable utilisation of peat for agriculture development is actually to prolong the lifespan of the productivity of the peat in relation to its drainability by proper water management.

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